A NEW PERSPECTIVE ON CANDOR CHASMA: LAND OF KNOBS. Marjorie A. Chan[1], Chris H. Okubo[2], Jens Ormö[3], Goro Komatsu[4] and the HiRISE Team[2]. [1]Department of Geology & Geophysics, University of Utah (135 S 1460 E, Salt Lake City, Utah 84112 USA marjorie.chan@utah.edu). [2]Lunar and Planetary Laboratory - University of Arizona (Tucson, AZ 85721).[3]Centro de Astrobiología (INTA/CSIC), Instituto Nacional de Técnica Aeroespacial (Ctra de Torrejón a Ajalvir, km 4, 28850 Torrejón de Ardoz, Madrid, Spain). [4]International Research School of Planetary Sciences, Università d'Annunzio (Viale Pindaro 42, 65127 Pescara, Italy).

Introduction: HiRISE (High Resolutiton Imaging Science Experiment) imagery and topography reveal numerous prominent and distinctive positive relief knobs amidst the layered deposits in West Candor Chasma, Mars. These steep, conical knobs (up to tens of meters tall and hundreds of meters wide at the base) rise up as features more resistant to weathering, and some appear to be mineralogically different from the surrounding host rock layers. Here we document the knobs and present several possible origin interpretations for these knobs utilizing terrestrial Earth analogs. The knobs have significant application to inferring relative timing of events, and further interpreting fluid flow and weathering conditions of Mars history.

Mapping Methods: Several data sets were utilized for mapping and observations of knobs in southwest Candor Chasma: THEMIS (~20 m/pixel) and CTX (~6 m/pixel) data were used for regional context maps, and HiRISE imagery (~30 cm/pixel) and digital elevation models (DEMs; 1 m postings) were used to analyze specific areas. HiRISE red, blue-green, near infrared channels respectively were used to construct RGB 'enhanced' color images. HiRISE DEMs were generated using a stereo image method [1]. CRISM mineral indicator maps were superimposed on the HiRISE data to attempt to detect correlations between the knobs and mineral composition.

Knob Characteristics: CTX images of southwest Candor Chasma (Fig. 1) show prominent scattered spots amidst the layered deposits. Upon close inspection of HiRISE images, these individual, "isolated" spots show positive relief, with conical to relatively steep-walls. These are herein referred to as knobs that show relatively rounded to flat tops with a possible cap lithology, to more peaked "pointy" tops. Southwest Candor Chasma shows the densest concentration of knobs. The sizes of the knobs are highly variable from small ones (tens of meters in diameter) that appear to be more closely spaced, to larger knobs with larger diameters (~ hundreds of meters) and taller heights. Some knobs show shoulders and more "mesa" types of expressions, especially in the westernmost part of Candor Chasma, where the knobs are so tightly spaced and of uniform height that they appear to form the remnants of a dissected bed in the layered deposits. However, other sporadic knobs occur as distinct topo-

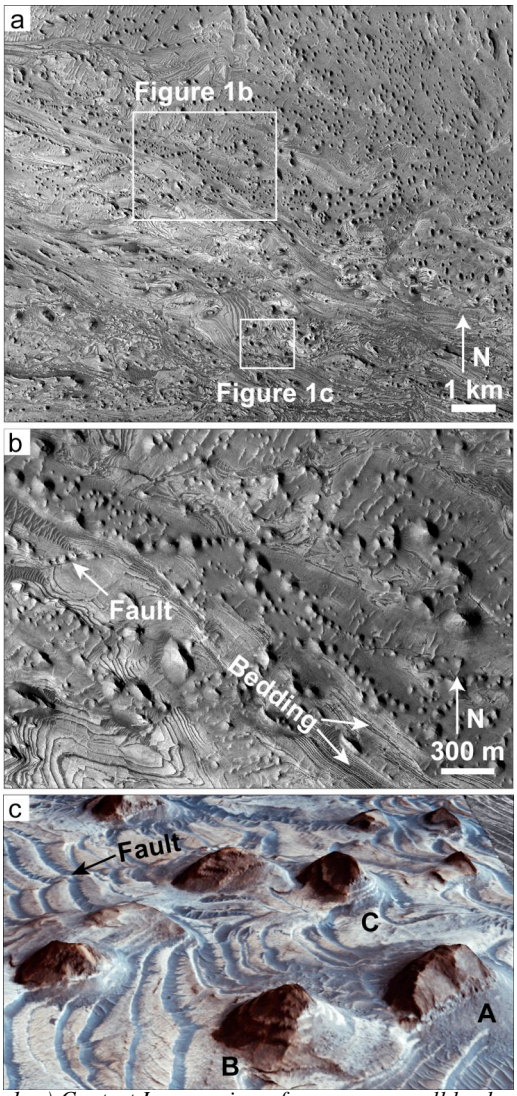

Fig. 1. a) Context Imager view of numerous small knobs with inset box locations of images in southwest Candor Chasma. Illumination is from left. Subscene from CTX image P06_003474_1735_XI_05S076W_070424. b) Some knobs show an apparent alignment with faults. High concentrations of knobs can also occur along some bedrock layers or show no apparent spatial correlation with faults or layering. Illumination is from left. HiRISE image PSP_003540_1735. c) Knobs in HiRISE enhanced color images commonly show an unconformable cap or mantling of dark-toned material. Blue tones of dunes is consistent with basaltic sand. Some knobs show a pit at their peaks. Perspective view toward the east with no vertical exaggeration. Unconformable contact at the base of the brown colored rocks has variable elevations and orientations amongst the knobs. HiRISE image PSP_003540_1735.

graphic features despite a relatively great distance (kilometers) to escarpments of layered deposits of similar elevation, further indicating their inherent resistant nature and the likely independence from resistant beds (i.e., an origin other than eroded and weathered pre-existing layers).

A number of the tops of the knobs and perhaps some of the interior appear to be remnants of a more resistant lithology that caps the knobs and helps protect the underlying pedestal lithology. Layering visible along the sides of some knobs may go through the knob or they may be a remnant of the surrounding layered deposits. However, there are also rows of knobs cross-cutting the general trend of the layers. This suggests that the formation of some knobs is controlled by geologic discontinuities such as faults and major fracture zones (Fig. 1b). A few knobs appear to have a central depressed pit on top.

Many of the knobs show a preferential dark brown coloration in the HiRISE enhanced color data, suggesting a different chemical composition, typically on the top and northeast sides of the knobs (Figs. 1b&c). This brown tone in the HiRISE enhanced color is consistent with iron oxide. CRISM mineral indicator maps [2] suggest an increase in iron oxides in proximity to the mounds, which may imply a water-rich environment during the deposition or during the diagenesis. This interpretation is consistent with OMEGA data [3], which suggests the presence of polyhydrated sulfates elsewhere in West Candor Chasma and thus a water-rich depositional or diagenetic setting. OMEGA data do not allow exact correlations of the spectra and the knobs due to their low spatial resolutions.

Origins and Interpretations: The knobs are interpreted to either be internally composed of a different and more resistant material, or at least to be capped by remnants of resistant material that could either be sourced by the internal structure of the knob, or be part of a pre-existing overlying layer. In either case, subsequent shaping of the topography and weathering likely contributed to material accumulation, and perhaps a lag deposit on the eastern slopes of the knobs.

We propose 4 possible interpretations based on terrestrial analogs and geologic processes that would produce the observed knob relationships (each with its own pros and cons):

A. Diagenetic cemented knobs.
B. Primary synsedimentary liquefied and injected sediment feeder "pipes" knobs.
C. Fumarole knobs.
D. Erosional remnants of pre-existing overlying strata or hoodoos.

Discussion: Overall, we interpret the knobs to be largely erosional due to differential weathering of more resistant materials either capping or comprising part of the interior neck or pipe of the knobs. At some places, either layers or faults seem to be eroded out and then transition laterally into knobs as evidenced by the change to elongated hills. But there are some knobs with more organized spatial distributions, which suggest that diagenetic pipes, synsedimentary pipes, or fumaroles cannot be excluded.

Currently, we favor a diagenetic cementation origin for the very isolated knobs that could also be superimposed on some liquefied sediment injectite type of pipes/cylinders. This could explain spacing organization of knobs across large areas of Southwest Candor, and could explain brown coloration from different mineralogies that are resistant to weathering. Fumaroles cannot be ruled out entirely either as they may produce a similar type of organization. More specific mineralogy could help determine whether this fumarole interpretation is plausible. In either the diagenetic cementation, injectite pipe, or fumarole origins, all of these suggest active and mobile groundwater or hydrothermal fluids.

Summary: A new perspective on Candor Chasma as a land of spectacular geomorphic knobs is now documented and imaged in detail from recent HiRISE images. Knobs show positive relief on the order of up to of tens of meters that is more resistant than the surrounding layered deposits. It is reasonable that the knobs are related to fluid movement in past Mars history either via diagenetic pathways, injectite pipes, fumaroles, or surface water erosion and weathering. There are multiple working hypotheses for the exact origin of the knobs that could be refined by more detailed mineralogic investigations. These remarkable features of Mars are enhanced by wind action and weathering, and may hold records of Mars past global water cycle.

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